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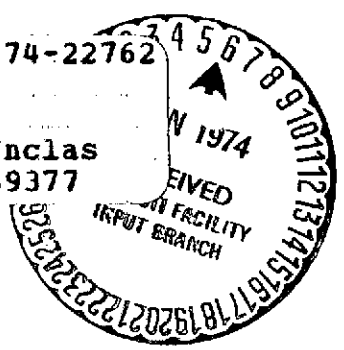
CHANGES IN THE CONCENTRATION OF POTASSIUM, SODIUM AND CALCIUM AS THE RESULT OF ENDURANCE EFFORT

E. Preisler and R. Kadza

Translation of "Zmiany stezenia potasu, sodu i wapnia w surowicy krwi pod wplywem wysilkow wytrzymalosciowych," Wychowanie Fizyczne i Sport, Vol. 11, No. 4, 1967, pp. 53-61



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16. Abstract

The authors determined the potassium, sodium and calcium levels in the venous blood serum in 122 persons, before and after endurance efforts of varying intensity (80 min track and field exercises, gymnastics, 1500 m swimming and bus driving). The authors found that the potassium and sodium levels decreased after strenuous effort, whereas the calcium level tended to increase.

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CHANGES IN THE CONCENTRATION OF POTASSIUM, SODIUM AND CALCIUM AS THE RESULT OF ENDURANCE EFFORT

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In a previous study we observed changes in the concentration /53* of electrolytes in the blood serum resulting from relatively intense endurance efforts (boat rowing over a distance of 200 m in about 7 min and swimming 400 m in 4.5-5.5 min). The large increase in the lactic acid concentration during these efforts (among the rowers, 109.0-150.0 mg% and among the swimmers, 93.6-128.9 mg%) indicates a disturbance in the steady state. The electrolyte concentrations that were determined under these conditions showed a drop in the potassium concentration among 2/3 of the persons studied during small changes in the sodium and calcium concentration.

Our present studies pertain to changes in the same electrolytes in the blood serum resulting from different types of efforts. The loads were sustained endurance efforts during which the changes in the lactic acid concentration were not large (they fluctuated in the range 8.6-46.0 mg%). The alkaline reserve level was reduced to 58-25% of the volume. Hence, it can be assumed that, unlike under the previous loads, the physical efforts investigated in this study were made under steady-state conditions.

Method

The changes in the concentration of potassium, sodium and calcium in the blood serum resulting from various types of endurance

* Numbers in the margin indicate pagination in the foreign text.

efforts were studied. Altogether, 122 persons, whose ages ranged from 14 to 45 years, were examined. The potassium and sodium were determined with the aid of a flame photometer and the calcium, by the Waard method.

The electrolyte studies were a part of the joint physiological (respiratory, metabolism, changes in the circulatory system) and biochemical studies (carbohydrates, fat and protein changes), the results of which are presented in other studies [4, 9, 10, 11, 12].

The loads consisted of three kinds of endurance efforts: /54
a) 80-min track and field exercises held in special facilities (alternating gymnastics, motor games and athletics); b) 1500 m swimming (in 15-17 min); c) professional bus driving on three routes (340 km/8 hours, 600 km/15 hours and 230 km/12 hours).

The particular number of persons examined after each load (given in Tables I, II, and III) will be stated during the description of the results.

The results were calculated statistically, taking into account the arithmetic mean, the standard deviation, the standard error of the mean and the level of significance.

Results

Potassium

The changes in the potassium concentration after moderately intense endurance efforts were comparatively small.

The 80-min exercises, during which 75 persons in the 17-26 year age group were examined (36 men and 39 women), caused a drop in the potassium level in the blood serum in 43 persons,

an increase in 22 persons, and no change in 10 persons. In this group of efforts, a greater reduction in the potassium concentration was detected after the athletic loads (in eight persons, a 0.55-1.05 meq/ℓ drop, an average 0.78 meq/ℓ drop, and a slight increase in three persons).

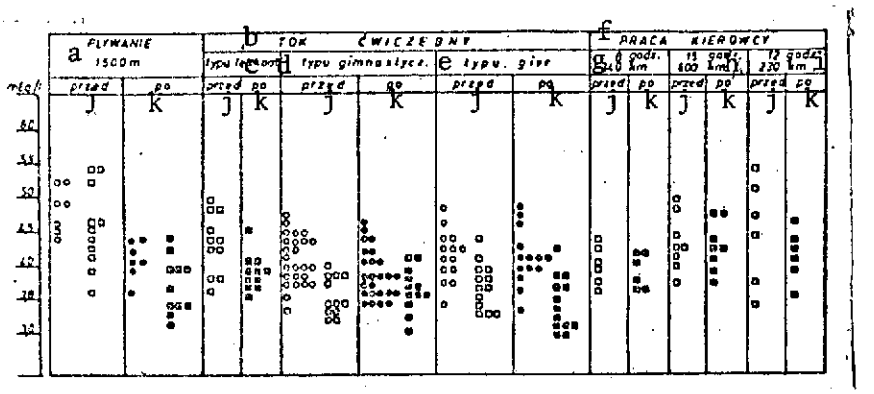

Fig. 1. Changes in potassium level in blood serum as a result of endurance efforts of various intensity.

Legend: o Women before effort □ Men before effort
● Women after effort ■ Men after effort

Key:
a. 1500 m swimming
b. Routine exercises
c. Athletics
d. Gymnastics
e. Games
f. Driving
g. 340 km/8 hours
h. 600 km/15 hours
i. 230 km/12 hours
j. Before
k. After

The changes among the 20 drivers that were examined, resulting from the work involved in driving a bus, were also small and nonuniform, especially after a day's work. In seven persons, a relatively large drop occurred (on the average 0.60 meq/ℓ), whereas the increases were insignificant (Table 1, Fig. 1).

TABLE I. POTASSIUM CONCENTRATION IN BLOOD SERUM AFTER VARIOUS ENDURANCE EFFORTS (MEAN VALUES)

Type of effect	Number of persons	Potassium in meq/ℓ						Significance
		before effort			after effort			
		Arithmetic mean	Standard deviation	Standard error of mean	Arithmetic mean	Standard deviation	Standard error of mean	
1500 m swimming	11 ♂	4.53	0.59	0.18	3.68	0.41	0.12	+
	7 ♀	4.82	0.32	0.12	4.11	0.28	0.11	+
Routine exercises								
Athletics	11 ♂	4.20	0.49	0.15	3.85	0.21	0.06	+
Gymnastics	12 ♂	3.48	0.30	0.09	3.59	0.33	0.09	—
	25 ♀	3.96	0.35	0.07	3.82	0.35	0.07	—
Games	13 ♂	3.73	0.31	0.09	3.48	0.39	0.11	—
	14 ♀	4.09	0.36	0.10	4.16	0.42	0.11	—
Driving:								
340 km/8 hr	6 ♂	3.95	0.31	0.13	3.77	0.26	0.11	—
600 km/15 hr	8 ♂	4.28	0.41	0.14	4.22	0.35	0.12	—
230 km/12 hr	6 ♂	4.42	0.79	0.32	4.09	0.36	0.15	—

An intense endurance effort caused a greater drop in the potassium level in the blood serum; after swimming 1500 m (11 boys and seven girls in the 14-17 year age group), a /56
0.50-2.02 meq/ℓ drop occurred in 13 persons, and a 0.16-0.27 meq/ℓ drop in five persons.

The reduced potassium levels in the blood serum after the 80-min athletic exercises and the swimming are statistically significant.

Sodium

The changes in the sodium concentration in the blood plasma also depended on the intensity of the effort, since they were noted in particular among drivers after night work (Table II, Fig. 2). The changes after the 80-min exercises were small and nonuniform (a 6.4 meq/ℓ drop in 32 persons, an average 6.4 meq/ℓ

drop, an average 7.1 meq/ℓ increase in 27 persons, and no change in eight persons).

TABLE II. SODIUM CONCENTRATION IN BLOOD SERUM AFTER VARIOUS ENDURANCE EFFORTS (MEAN VALUES)

Type of effect	Number of persons	Sodium in meq/ℓ						Significance
		before effort			after effort			
		Arithmetic mean	Standard deviation	Standard error of mean	Arithmetic mean	Standard deviation	Standard error of mean	
1500 m swimming	11 ♂	144.1	7.3	2.2	140.1	5.4	1.6	—
	7 ♀	141.7	2.9	1.1	137.5	6.6	2.5	—
Routine exercises								
Athletics	11 ♂	143.1	5.2	1.6	145.1	9.7	2.9	—
Gymnastics	12 ♂	142.4	4.1	1.2	141.1	4.5	1.3	—
	18 ♀	143.4	6.5	1.5	141.4	4.1	1.0	—
Games	12 ♂	140.6	5.4	1.6	143.1	5.9	1.7	—
	14 ♀	143.2	4.1	1.1	140.4	4.7	1.3	—
Driving:								
340 km/8 hr	5 ♂	140.2	4.1	1.8	138.2	5.6	2.5	—
600 km/15hr	9 ♂	142.6	3.7	1.2	146.1	7.2	2.4	—
230 km/12hr	8 ♂	149.9	6.4	2.3	141.8	7.3	2.6	+

After the swimming effort, the changes in the sodium concentration were greater -- a drop was detected in 12 persons (the drop was relatively large in eight persons, with an average 7.9 meq/ℓ drop) and a slight increase in six persons (in one person, the increase was 17.3 meq/ℓ). /57

However, the largest deviations occurred among drivers after night work (230 km/12 hours): in five out of the eight drivers, the average drop was 14.7 meq/ℓ , an increase was detected in two drivers (average increase 4.4 meq/ℓ)) and in one driver no changes have been detected. Among the drivers from the remaining routes, the changes were small (Table II, Fig. 2).

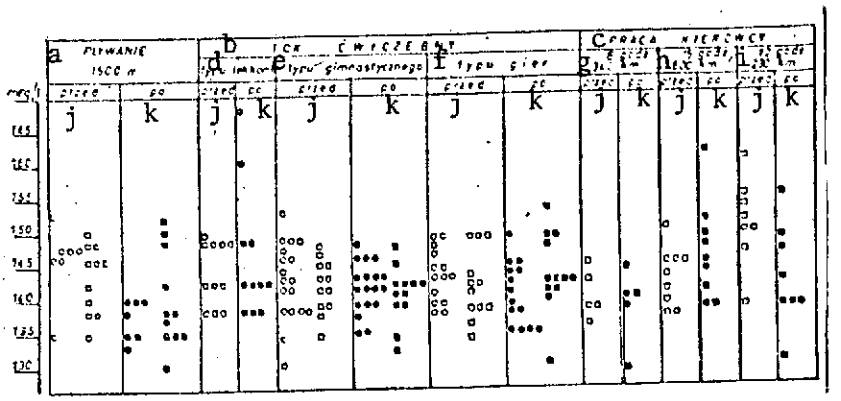

Fig. 2. Changes in sodium level in blood serum as a result of endurance efforts of various intensity.

Legend: o Women before effort ☐ Men before effort
● Women after effort ■ Men after effort

Key:
a. 1500 m swimming
b. Routine exercises
c. Driving
d. Athletics
e. Gymnastics
f. Games
g. 340 km/8 hours
h. 600 km/15 hours
i. 230 km/12 hours
j. Before
k. After

Calcium

The changes in the calcium concentration in the blood serum were least characteristic and they were not significantly correlated with the intensity of the effort. After all efforts that were investigated, a slight tendency toward an increase was detected among 65 persons (out of 122), a slight decrease was detected among 47 persons, and no changes among 10 persons.

The average increase among the persons participating in the 80-min exercises was 0.27 meq/ℓ, among the drivers, 0.32 meq/ℓ, and after the swimming effort, 0.51 meq/ℓ.

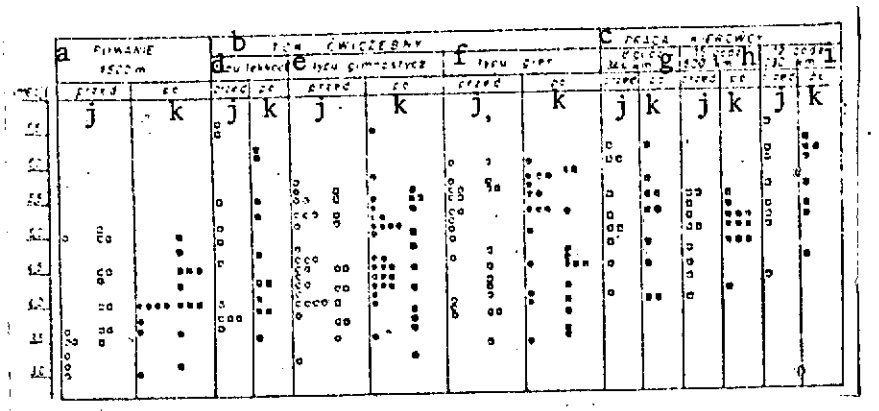

Fig. 3. Changes in calcium level in blood serum as a result of endurance efforts of various intensity.

Legend: o Women before effort □ Men before effort
● Women after effort ■ Men after effort

Key:
a. 1500 m swimming
b. Routine exercises
c. Driving
d. Athletics
e. Gymnastics
f. Games
g. 340 km/8 hours
h. 600 km/15 hours
i. 230 km/12 hours
j. Before
k. After

The drops in the concentration in the same order were, respectively: 0.33 meq/ℓ, 0.31 meq/ℓ and 0.56 meq/ℓ.

Discussion

It follows from the studies that were presented that the effect of sustained endurance efforts on the electrolyte concentration in the blood serum was reflected comparatively markedly in the changes in the potassium and sodium level, and less markedly in the calcium concentration.

TABLE III. CALCIUM CONCENTRATION IN BLOOD SERUM AFTER VARIOUS ENDURANCE EFFORTS (MEAN VALUES)

Type of effort	Number of persons	Calcium in meq/ℓ						Significance
		before effort			after effort			
		Arithmetic mean	Standard deviation	Standard error of mean	Arithmetic mean	Standard deviation	Standard error of mean	
1500 m swimming	11 ♂	4.31	0.58	0.17	4.22	0.48	0.14	—
	7 ♀	3.58	0.67	0.25	3.76	0.37	0.14	—
Routine exercises								
Athletics	11 ♂	4.81	1.09	0.33	4.75	0.93	0.28	—
Gymnastics	12 ♂	4.69	0.77	0.22	4.78	0.85	0.25	—
	25 ♀	4.63	0.64	0.13	4.76	0.64	0.13	—
Games	13 ♂	4.89	0.94	0.26	4.54	0.68	0.19	—
	15 ♀	5.04	0.68	0.18	5.16	0.78	0.20	—
Driving:								
340 km/8 hr	10 ♂	5.24	0.70	0.22	5.08	0.73	0.23	—
600 km/ hr	10 ♂	4.90	0.54	0.17	5.02	0.37	0.17	—
230 km/12 hr	8 ♂	5.44	0.70	0.25	5.64	0.59	0.21	—

After the three types of endurance efforts that were discussed, the potassium concentration was decreased in 64% of the persons examined, slightly increased in 26% of the persons examined, and no changes occurred in 10% of the person examined. The largest drop in the potassium concentration in the blood serum occurred after the swimming race (1500 m in 15-17 min) among all contestants (in 13 persons, a 0.5-2.02 meq/ℓ drop and in five persons, a 0.16-0.27 meq/ℓ drop). Its level was reduced to 3.12 meq/ℓ. The drop in the potassium concentration observed among the swimmers deserves attention, since it was also detected by us after a different type of swimming effort (400 m) in our previous studies [10]. /58

After the 80-min exercises and after many hours of driving, the changes were small.

Sustained intense endurance efforts are generally accompanied by relatively large water and weight losses, as a result of which

comparatively large changes occur in the electrolyte balance in the system. One possible factor causing the reduced potassium level in the muscle cells and its greater urinary elimination is the drop in the glucose concentration in the blood serum, which occurs during physical efforts of this type. The reverse phenomenon, connected with the passing of the potassium into the cell, occurs, according to some authors, during increased adrenaline secretion and the resulting hyperglycemia [2, 6, 14].

Studies made on rats [15] have shown that the intracellular potassium concentration in the muscle drops after a sustained, exhausting endurance effort. However, the intracellular sodium concentration increases only slightly. These studies indicate that the level of both electrolytes does not undergo considerable changes in the extracellular fluid. The reduced potassium level in the blood serum after an intense effort should be reflected, in view of the studies that were made on animals, by its drop in the muscle cell. This phenomenon is undoubtedly related to changes in the permeability of the cell membrane occurring in conjunction with the polarization, depolarization and repolarization processes. It is assumed that, as a result of sustained intense muscular activity, a disturbance occurs in the repolarization process in the muscle cell (blocking of the return of the potassium ions into the cell). Keeping in mind the continuous electrolyte exchange between the intracellular and extracellular fluids, the plasma and specific tissues, the assumption must be made that the potassium ions whose concentration was reduced in the blood serum (and in the muscle cell) were used up by other tissues or eliminated through the kidneys [5]. The studies by Yudilevich and de Julian [16] indicate a very vigorous electrolyte exchange between the heart muscle and other tissues. In particular, the study investigated the concentration of potassium, sodium, iodine and rubidium ions in the blood serum after it passed through the cardiovascular system. It was found that the potassium exchanged

with tissue ions was 69% and the sodium 74% in one blood cycle through the coronary vessels.

It follows from the studies that were made on animals that training increases the potassium concentration in the muscles. After exhausting work, its reduction is greater in conditioned muscles than in unconditioned muscles. The potassium and sodium concentration in the extracellular fluid does not change as a result of training [15].

The drop in the sodium concentration in the blood serum after a sustained, intense endurance effort (an average 7.9 meq/ drop after 1500 m among the swimmers) is greater than after a speed endurance effort (after 400 m swimming and 2000 m rowing, /59 the average drop was 1.0 meq/). The drop in the potassium was large after both types of efforts, a fact that was already emphasized. The drop in the sodium level among drivers after 12 hours of night driving (on the average, 14.7 meq/) is striking, since the changes in the level during daytime driving and after the 80-min exercises are small. Generally, the changes in the sodium concentration are quickly equalized, as demonstrated by the studies of the electrolyte exchanges in the coronary vessels that were mentioned above [16]. Physical conditioning does not cause relatively large changes in the sodium concentration. Unlike the potassium concentration, its level does not undergo comparatively large changes as a result of training. Also, during the large drop in the potassium level in the cell, immediately after the effort, the sodium concentration in the cell increases only slightly [15]. No significant changes have been detected in the extracellular fluid. They are more pronounced in the venous blood after endurance efforts.

The changes in the calcium concentration in the blood serum after the endurance efforts that were discussed did not occur uniformly, and they were generally small. The tendency toward an increase

that was detected among 53% of the persons examined, primarily after the 80-min gymnastics exercises or after several hours of driving among the drivers, deserves a certain amount of attention. In our previous studies [10] pertaining to speed endurance efforts (400 m swimming, 2000 m boat rowing), the calcium concentrations were reduced in the majority of persons examined. The increases in the concentration of this electrolyte were smaller, and they occurred less frequently (predominantly after a swimming race).

Greater increases in the calcium concentration in the blood serum were detected in fatigue states after the effort [3]. A certain amoung of light is shed on the mechanism for the effect of calcium ions on the activity of a muscle cell in relation to a neurocyte (increased irritability accompanied by a drop in the concentration and vice versa) by studies made in vitro, which detected that the mitochondria absorb active calcium ions, resulting in stepped-up oxidative processes [1, 7]. The capacity to maintain a high calcium ion concentration in the mitochondria is high during rest, and, to a certain degree, independent of the ion concentration in the surrounding medium. It is difficult to say to what extent the changes in the calcium concentration in the blood serum reflect its level in the cell, since the calcium balance in the system is very complicated (among other things, training increases the amount of salts of calcium deposited in the bones, especially at the muscle insertions, whereas, in contrast, akinesia is accompanied by greater calcium losses).

It can be stated on the basis of the observations that were made that the deviations in the concentration of the electrolytes that were investigated are correlated with a number of other changes: an increase in aminotransferase activity, in particular, alanine activity in swimmers and drivers after driving in very brisk traffic [11], increased activity of the respiratory system,

a hypotensive reaction of the circulatory system to the endurance test, with changes in the ECG curve, and other factors [9]. These changes are correlated with the mechanism of fatigue which occurs after the exertion.

Conclusions /60

1. Sustained, very intense endurance efforts have an effect on the reduction of the potassium and sodium level in blood plasma.

2. After an endurance effort of moderate intensity, the changes in the potassium and sodium concentration are small and nonuniform.

3. The changes in the potassium concentration resulting from a physical effort are greater, under the same physiological conditions, than those which occur in the sodium in blood plasma.

4. The calcium level in the blood serum tends to increase after sustained physical efforts.

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